Determinants of cockroach and mouse exposure and associations with asthma in families and elderly individuals living in New York City public housing

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Background: Asthma prevalence is high in the inner city, and morbidity has been associated with cockroach and mouse allergens.

Objective: To characterize the relationships among pests, allergens, pesticides, and asthma in New York City public housing.

Methods: In 324 apartments, dust samples collected from beds and kitchens were analyzed for cockroach (Bla g 2) and mouse (mouse urinary protein [MUP]) allergens, pest populations were monitored, and residents were interviewed about home characteristics and asthma symptoms.

Results: Cockroaches were found in 77% of the apartments, and evidence of mice was found in 13%. Allergens and pesticide use were associated with pest infestation, and 15% of residents reported using illegal pesticides. The percentage of apartments with high allergen levels varied significantly by building (Bla g 2: $P = .002$; MUP: $P = .03$), as did the percentage of apartments with cockroaches ($P = .002$) and daily mouse sightings ($P = .02$). Thirty-seven percent of the apartments had at least 1 resident with physician-diagnosed asthma. In family buildings, apartments with high Bla g 2 levels had 1.7 times greater odds of having an asthmatic resident (95% confidence interval, 1.2–2.3). In senior citizen buildings, apartments with high MUP levels had 6.6 times greater odds of having an asthmatic resident (95% confidence interval, 1.4–31.7), controlling for smoking and other potential confounders.

Conclusions: Previous studies have identified home characteristics associated with the presence of cockroaches and mice, but the present findings suggest that building-level characteristics can affect high pest exposure. Furthermore, the high asthma prevalence in residents and the use of illegal pesticides highlight the need for safe and effective building-wide pest control strategies.

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INTRODUCTION

In major cities in the United States, cockroaches and mice are commonly encountered sources of allergens associated with asthma in children.[1–5] In the National Cooperative Inner City Asthma Study (NCICAS), the combination of exposure and sensitization to cockroach allergens has been shown to increase rates of hospitalizations, missed school days, and days with wheezing in asthmatic children.[1] In the same cohort, asthmatic children with mouse allergen levels higher than the median in their kitchen dust had greater odds of having positive mouse skin test results than those with mouse allergen levels less than the median.[2] However, less is known about the association between cockroach and mouse allergen levels and asthma prevalence in the general population.[6–8] Furthermore, previous literature, to our knowledge, has not examined whether cockroach or mouse allergen exposures are also associated with asthma prevalence in the inner-city elderly population.

As a result of recent findings, mouse and cockroach allergen exposures have been the target of childhood asthma intervention studies conducted in the inner city.[9–14] Although some studies[15–17] have examined associations among cockroaches, mice, their allergens, and pesticide use, little is known about the building-related factors that determine allergen levels in apartments. We believe that a better understanding of allergen variability (within apartments, within buildings, and between buildings) and of how allergens in apartments are affected by building characteristics will improve the efficacy of future interventions.

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An opportunity to address these issues was provided by a study of the impact of integrated pest management (IPM) on pests, allergens, and asthma in public housing developments. Collaborations among departments of health, housing agencies, and researchers offer a unique opportunity to address asthma in the urban environment.[18–20] This study was sponsored by the Columbia Center for Children's Environmental Health (CCCEH) and the New York City Department of Health and Mental Hygiene (DOHMH) and was conducted in collaboration with the New York City Housing Authority (NYCHA). Using baseline data from this study, we examined 2 questions: (1) To what extent do levels of pests and pest allergens vary across housing developments, buildings, apartments, and rooms within apartments? (2) Is there a difference in the relationship between current levels of cockroach and mouse allergens and the prevalence of asthma and asthma morbidity in family resident and elderly resident buildings?

METHODS

Research Setting

This research was conducted in New York City public housing developments selected by NYCHA. The selected developments were in reasonable structural condition, had an active residents' association, and had no capital projects scheduled in the next year. The 5 selected developments in Bushwick (in the borough of Brooklyn) and East Harlem (in the borough of Manhattan) met these criteria and are located in neighborhoods with high rates of hospitalization for childhood asthma (12.7 and 29.3 per 1,000 children through age 14 years, respectively).[21]

Before beginning the IPM intervention and evaluation in each development, representatives from the CCCEH, the DOHMH, and NYCHA met with the residents' associations to discuss plans for the IPM intervention and evaluation and to solicit their input. The relationship with the residents' associations has continued throughout implementation of the programs. Members of the residents' associations served as liaisons between residents and the IPM and evaluation teams, answering residents' questions about the program and providing informal feedback to the research and evaluation teams.

Sampling and Recruitment

Within the developments, the DOHMH and the CCCEH selected buildings for the study to represent several NYCHA housing types. The sample included 2 senior citizen high-rise buildings, 5 family high-rise buildings, and 6 family townhouses (3-story buildings). Residence in family buildings was not restricted by resident age or by virtue of having multiple residents in the household. We randomly selected 516 apartments (51% percent of all apartments in the evaluation buildings) to be asked to participate in the study using a random number generator. Residents of these randomly selected apartments were enrolled via information tables in building foyers, telephone calls, and door-to-door canvassing. In an attempt to reach working residents, telephone calls were made during the day and in the evening, and evaluation visits were scheduled for Mondays through Saturdays. We enrolled and completed baseline evaluations in 324 apartments (63%). Residents in 137 apartments (27%) refused to participate, 27 (5%) could not be contacted, 10 (2%) were not capable of providing informed consent, and 3 ($<$1%) were moving in the next 3 months. Nine apartments (2%) received the IPM intervention before the baseline visit could be conducted, and 7 (1%) were vacant. The evaluation protocol was approved by the institutional review boards of Columbia University Medical Center and the DOHMH, and all the participants provided written informed consent.

Data Collection

Baseline evaluations were conducted in East Harlem between August 1 and November 30, 2002, and in Bushwick between October 2003 and May 2004. Trained research workers, fluent in Spanish and English, conducted a home visit during which they collected allergen samples, interviewed the head of the household in the language of his or her choice, and placed cockroach and rodent monitoring equipment. The monitoring equipment was recovered from the home 1 week after the initial home visit. The variety of translators available through NYCHA enabled the participation of residents speaking other languages. This was especially helpful for recruiting and interviewing several Chinese-speaking residents.

Pest populations were evaluated through resident reports and objective monitoring. We asked residents how often and where they saw cockroaches, mice, and rats in the past 3 months. We monitored cockroach populations using pheromone glue traps (Victor Roach Pheromone Traps; Woodstream Corp, Lititz, PA). Five traps were placed in specified locations in the kitchen, 1 in each bathroom, and 1 in each bedroom. Traps were collected after 7 days and frozen for 24 hours. Trained research workers counted the number of adults, nymphs, and egg cases up to 100 and identified cockroach species. The number of kitchen cockroaches was calculated by summing the number of nymphs and adult cockroaches caught in the kitchen. If the traps were not collected after exactly 7 days, the total was standardized to reflect a 7-day period. Likewise, if fewer than 5 traps were collected in the kitchen, the total was standardized to account for the missing traps. Whereas previous studies have evaluated mouse populations by inspecting for rodent droppings and asking residents about mouse sightings,[14] we piloted an objective measure of mouse presence using nontoxic, nonrodenticidal bait blocks (Census Bait Blocks; York Distributors, Long Island, NY) placed in petproof and childproof cases (Protector RTU Mouse Stations; York Distributors). One 20-g bait was placed in each room in the apartment. Baits were collected after 7 days, and the difference in the weight of the block (preplacement minus postplacement) was recorded. Mouse bait blocks were considered positive for mice if at least 1 g of bait was consumed. The validity of this measure was evaluated by comparing objective monitoring results with resident-reported mouse sightings and measured allergen levels.

To evaluate personal pest control practices and pesticide use, we asked residents whether they had used any of 8 different pest control products in the past 3 months: roach bait stations, sprays, bombs and foggers, boric acid, roach gels, roach motels or sticky traps, Tempo, and cockroach chalk. Trained research workers inspected conditions in the kitchen. Evaluation of clutter was based on the percentage of surface area filled with items other than appliances, containerized food, or clean dishes that were relevant to each area (eg, countertop, stovetop, and top of refrigerator). Specifically, the percentage coverage was categorized as follows: none, 0% to 5%; low, more than 5% to 20%; moderate, more than 20% to 40%; and heavy, more than 40%. They also rated the amount of open food (none, low, moderate, or heavy) in 3 locations. The 3 items were scored, and any apartment with at least 1 heavy rating or the equivalent (eg, 2 moderate ratings or 3 low ratings) was classified as having open food or clutter.

We evaluated asthma prevalence and severity during the interview. We asked if anyone living in the apartment had been diagnosed as having asthma by a physician. For each diagnosed asthmatic individual, we asked about symptoms during the past 2 weeks and about asthma-related emergency department visits, physician visits, days of work or school lost, and caretaker days lost in the past 3 months. We also asked how many people in the apartment smoked cigarettes. Asthma severity was evaluated based on the number of days of coughing, wheezing, or whistling in the chest in the 14 days preceding the interview, according to National Heart, Lung, and Blood Institute guidelines.[22,23]

Separate dust samples from beds and kitchens were collected using a Mitest dust collector (Indoor Biotechnologies Inc, Charlottesville, VA) attached to a canister vacuum cleaner (Eureka Mighty Mite; Electrolux Home Care Products North America, Peoria, IL). Kitchen floors and beds in up to 3 bedrooms (including the beds of any asthmatic patients) were each sampled for 3 minutes. Bed samples were collected by vacuuming the upper half of the bed near the pillows. Samples were frozen at $-20°C$ for 24 hours immediately after collection. Dust samples were extracted with phosphate-buffered saline with 0.05% Tween 20 and assayed for mouse (mouse urinary protein [MUP]) and cockroach (Bla g 2) allergens as previously described.[8,24] The MUP reagents were obtained from Greer Laboratories Inc (Lenoir, NC), and the Bla g 2 reagents were obtained from Indoor Biotechnologies.

Data Analysis

The number of kitchen cockroaches trapped was not normally distributed and could not be normalized through log transformation, so nonparametric methods were used to examine relationships with this variable. We used the Kruskal-Wallis test for variance to examine the relationship between the number of cockroaches trapped and resident-reported cockroach sightings. We used the Mann-Whitney U test to examine the relationship between trapped cockroaches in the kitchen and binary variables, including the use of spray pesticides, the presence of children in the home, food, and clutter. The presence of mice was analyzed as a binary variable using resident reports and objective monitoring and was compared with other binary variables using the Pearson χ^2 test.

To evaluate relationships between allergen concentrations in different rooms within apartments, we computed correlation coefficients using the nonparametric Spearman ρ because bedroom MUP, kitchen MUP, and kitchen Bla g 2 levels could not be normalized. Samples below the limit of detection were assigned half of the lower limit of detection. In all other allergen analyses, allergens were treated as binary variables. Apartments in which kitchen Bla g 2 levels were greater than 8 U/g (which is equal to 0.32 μg/g) or at least 1 bed with a Bla g 2 level greater than 8 U/g were classified as having high kitchen or bed allergen levels, respectively. The threshold for high MUP levels was 1 μg/g. Odds ratios (ORs) were calculated comparing allergen levels with pest sightings, apartment conditions, and building type. To examine differences in allergens and pests in different buildings, Pearson χ^2 and Fisher exact tests were used.

Owing to notable differences between elderly resident and family resident buildings, we conducted a stratified analysis by building type. In the family building analysis, we used a Poisson regression model to account for the variable number of residents and asthmatic patients in each apartment. The multilevel model, which was constructed using the generalized estimating equation method (SAS version 9.1.3; SAS Institute Inc, Cary, NC), examined the relationship between the number of asthmatic patients in an apartment and bed allergen levels. We controlled for building-level effects, as well as smoking, the presence of children, and the number of residents in the apartment. In the analysis of the senior citizen buildings, because most residents in these buildings live alone, and no apartment had more than 1 adult with asthma, we constructed a logistic regression model. This model examined the relationship between the presence of a resident with asthma and bed allergen levels, controlling for building, smoking, and having more than 1 resident in the apartment.

We examined the relationship between high allergen levels and asthma morbidity, restricting the analyses to the 99 apartments with 1 or more asthmatic residents in which bed allergen samples were collected. Allergen levels in apartments in which 1 or more asthmatic residents reported symptoms in the past 2 weeks, health care utilization in the past 3 months, or lost work or school in the past 3 months were compared with allergen levels in apartments in which asthmatic patients reported no corresponding symptoms using the Pearson χ^2 test.

RESULTS

Table 1 profiles the 324 apartments evaluated at baseline. Apartments ranged in size from studios to 5-bedroom units.

Table 1. Description of the 324 New York City Housing Authority Apartments Whose Residents Participated in the Study*

	Apartments, No. (%)		
	In family buildings (n = 223)	**In senior citizen buildings (n = 101)**	**All (N = 324)**
Apartment location			
East Harlem	102 (46)	67 (66)	**169** (52)
Brooklyn	121 (54)	34 (34)	**155** (48)
Apartment is home to			
Children aged <18 y	92 (41)	1 (1)	**93** (29)
Children aged <7 y	46 (21)	0	**46** (14)
≥1 asthmatic individuals	104 (47)	14 (14)	**118** (36)
≥1 smokers	82 (37)	24 (24)	**106** (33)
No. of residents in the apartment			
1	72 (32)	92 (91)	**164** (51)
2	61 (27)	7 (7)	**68** (21)
3	27 (12)	1 (1)	**28** (9)
4	27 (12)	0	**27** (8)
≥5	36 (16)	0	**36** (11)
No. of years resident has lived in apartment			
<1	5 (2)	8 (8)	**13** (4)
1–4	31 (14)	31 (31)	**62** (19)
5–9	33 (15)	28 (28)	**61** (19)
10–19	75 (34)	24 (24)	**99** (31)
≥20	79 (35)	8 (8)	**87** (27)

* Some values do not sum to the appropriate totals because of missing questionnaire data.

Most residents interviewed had lived in their apartments for at least 10 years. Nearly half of the apartments studied were located in family high-rise buildings (47%), 22% were in family townhouses, and 31% were in senior citizen high-rise buildings. The population of the family buildings was largely adult (59% of the households had no children in residence).

Pest Populations

Table 2 describes pest populations and pesticide use at baseline. Cockroaches were reported or trapped in nearly every home we visited (95%). They were most commonly trapped in the kitchen (74%) and less often in the bathroom (35%) and bedroom (23%). Resident-reported cockroach sightings were significantly related to the number of cockroaches we detected in the kitchen ($P < .001$).

Mice were less common than cockroaches and were more evenly distributed throughout the apartment. Baits were positive for mice in 13% of the apartments (7% of kitchens, 12% of living rooms, 4% of bathrooms, and 7% of bedrooms) (Table 2). Baits were negative for mice in 81% of apartments in which residents reported seeing mice in the past 3 months and in 76% of apartments in which residents reported seeing mice every day.

Pesticide Use by Residents

Almost all the residents (98%) reported using pesticides in the past 3 months to control cockroaches, and most residents (88%) reported using lower-toxicity pesticides (baits, gels, boric acid, and glue traps) (Table 2). There was no significant association between the use of lower-toxicity pesticides and the severity of cockroach infestation. Most residents (63%) also reported using higher-toxicity pesticides, and residents with more cockroaches were significantly more likely to report using higher-toxicity pesticides (bombs or foggers, spray pesticides, Tempo, and pesticide chalk) ($P = .009$), particularly spray pesticides ($P = .002$).

A few residents (15%) reported using 2 pesticides that are sold illegally in New York City: Tempo and cockroach chalk. Tempo is a concentrated cyfluthrin powder manufactured for use by licensed pest control operators and intended to be mixed with water for application. The concentrated powder is sold on the streets, and residents reported sprinkling the powder in their apartments, an application method previously found to result in concentrations 200 to 400 times greater than recommended.[25] Cockroach chalk, which closely resembles chalk that children use, is also known as Chinese chalk and is not registered for use in the United States. Cockroach chalk contains the pyrethroid delta-methrin, although formulations may vary because the product is not regulated.[26]

Cockroach and Mouse Allergens

We collected allergen samples from kitchens in 321 apartments and from 365 beds in 269 apartments (in some apartments, we collected allergen samples from >1 bed). Overall, 93% of the apartments had at least 1 dust sample with detectable cockroach allergen, 90% were greater than 1 U/g and 71% were greater than 8 U/g. Mouse allergen was detectable in 84% of the apartments, but only 34% of the apartments contained more than 1.6 μg/g and 31% contained more than 2 μg/g. The median level of Blag 2 was 1.8 U/g in beds and 35.9 U/g in kitchens. The median level of MUP was 0.28 μg/g in beds and 0.50 μg/g in kitchens.

Table 2. Pest Sightings, Objective Pest Monitoring Results, and Pesticide Use by Residents*

	Apartments, No. (%)		
	In family buildings (n = 223)	In senior citizen buildings (n = 101)	All (N = 324)
Resident-reported daily cockroach sightings			
Never	12 (5)	10 (10)	**22** (7)
<1	23 (10)	19 (19)	**42** (13)
1–5	53 (24)	38 (38)	**91** (28)
6–9	29 (13)	9 (9)	**38** (12)
10–19	35 (16)	9 (9)	**44** (14)
≥20	70 (31)	15 (15)	**85** (26)
Cockroaches trapped in the apartment			
No	41 (18)	35 (35)	**76** (23)
Yes	182 (82)	66 (65)	**248** (77)
Mouse sightings in the past 3 mo			
Never	104 (47)	61 (60)	**165** (51)
<1 per week	49 (22)	19 (19)	**68** (21)
1–6 per week	23 (10)	9 (9)	**32** (10)
≥1 per day	45 (20)	11 (11)	**56** (17)
Baits positive for mice in the apartment			
No	186 (83)	93 (92)	**279** (86)
Yes	35 (16)	8 (8)	**43** (13)
Use lower-toxicity pesticides	204 (91)	80 (80)	**284** (88)
Baits	174 (78)	68 (67)	**242** (75)
Boric acid	73 (33)	27 (27)	**100** (31)
Gels	103 (46)	34 (34)	**137** (42)
Sticky traps	80 (36)	33 (33)	**113** (35)
Use higher-toxicity pesticides	148 (66)	56 (56)	**204** (63)
Bombs or foggers	26 (12)	1 (1)	**27** (8)
Chalk†	16 (7)	5 (5)	**21** (6)
Sprays	136 (61)	48 (48)	**184** (57)
Tempo†	24 (11)	11 (11)	**35** (11)

* Some values do not sum to the appropriate totals because of missing questionnaire data.

† These products are sold illegally. Tempo is registered to be used by licensed pest control operators only. Pesticide chalk is not registered for any use.

Allergen Variability Within Apartments

Allergen levels from different beds within apartments were strongly correlated for mouse allergen ($r = 0.68$; $P < .001$) and cockroach allergen ($r = 0.75$; $P < .001$) in the 78 apartments in which we collected dust samples from 2 or more bedrooms. Average bed allergen levels were moderately correlated with kitchen allergen levels (MUP: $r = 0.39$; $P < .001$; and Bla g 2: $r = 0.48$; $P < .001$). Cockroach allergen was significantly, but weakly, correlated with mouse allergen from beds ($r = 0.29$; $P < .001$) but not from kitchens ($r = 0.10$; $P = .09$).

Home Characteristics Associated With Allergen Variability Between Apartments

Allergen levels were related to several apartment-level factors (Tables 3 and 4). The presence of pests in the apartment was consistently and strongly associated with cockroach and mouse allergens. Bla g 2 in the kitchen was significantly associated with resident-reported cockroach sightings and objective cockroach monitoring (ie, trapping). The same was true for Bla g 2 in beds. However, resident-reported mouse sightings were a more consistent predictor of MUP than was bait-block mouse monitoring. Bait blocks were not significantly associated with MUP allergen levels in the kitchen, but they were associated with MUP levels in the bedrooms even when different cutoff points (0.5 and 2 g) were used as indicators for the presence of mice (OR, 2.6; 95% confidence interval [CI], 1.2–5.3; and OR, 2.6; 95% CI, 1.1–6.2; respectively).

Apartments with young children, open food, or clutter in the kitchen were significantly more likely to have high MUP and Bla g 2 levels in the beds. However, no significant association was seen between these 3 factors and kitchen allergen levels. Using a different threshold for high MUP levels (median, 0.28 μg/g), none of these 3 factors were significantly associated with high MUP levels. In fact, only resident report of mice remained significant using the median MUP level as the threshold.

Building Differences in Pests and Allergens

When examining building-level effects, we first examined differences in pest and allergen levels between apartments in senior citizen buildings and family buildings (Tables 1 and 2). Senior citizen buildings offer smaller apartments (studios

Table 3. Comparison of Apartments With High Cockroach Allergen (Bla g 2) Levels in Kitchens and Beds With Environmental Conditions*

Home characteristic	Kitchen dust samples (n = 321)			Bed dust samples (n = 269)		
	No.	Apts with high Bla g 2, %†	OR (95% CI)	No.	Apts with high Bla g 2, %‡	OR (95% CI)
Cockroaches trapped in the apartment						
Yes	245	80	7.7 (4.4–13.6)§	206	32	5.3 (2.0–14.0)§
No	76	34		63	8	
Resident sees >20 cockroaches daily						
Yes	84	89	5.1 (2.4–10.6)§	69	54	5.8 (3.2–10.6)§
No	235	62		198	17	
Site						
East Harlem	166	79	2.6 (1.6–4.3)§	147	36	3.5 (1.9–6.4)§
Bushwick	155	59		122	14	
Building type						
Senior citizen	100	64	0.7 (0.4–1.2)	93	20	0.6 (0.3–1.1)
Family	221	72		176	29	
Child aged <7 y lives in the apartment						
Yes	45	73	1.3 (0.6–2.5)	38	50	3.5 (1.7–7.1)§
No	275	69		230	22	
Open food in the kitchen						
Yes	47	79	1.8 (0.8–3.7)	42	60	5.9 (3.0–11.9)§
No	274	68		227	20	
Clutter in the kitchen						
Yes	105	76	1.7 (1.0–2.8)	91	41	3.0 (1.7–5.3)§
No	216	66		178	19	

Abbreviations: Apts, apartments; CI, confidence interval; OR, odds ratio.
* Some values do not sum to the appropriate totals because of missing questionnaire data.
† Samples with Bla g 2 levels greater than 8 U/g (1 unit = 40 ng) were categorized as high.
‡ At least 1 bed sampled in the apartment contained high Bla g 2 levels.
§ Significant at $P < .001$.

and 1-bedroom apartments) than family buildings, which include apartments with up to 5 bedrooms. Almost all the apartments in senior citizen buildings (92%) are home to only 1 resident compared with 32% of the apartments in family buildings. Residents in senior citizen buildings have lived in their apartments for significantly less time than residents in family buildings (only 32% of residents in senior citizen buildings have been in their apartments for at least 10 years compared with 69% in the remaining buildings; $P < .001$). Only 1 apartment in the senior citizen buildings had children. The use of lower-toxicity pesticides was less common in the senior citizen buildings compared with family buildings (80% vs 91%; $P = .003$). There was no significant difference between buildings in the use of spray and illegal pesticides. The median number of cockroaches trapped in senior citizen buildings was significantly lower than that in family buildings (2 vs 10; $P = .001$), and residents in senior citizen buildings were less likely to report seeing mice every day (11% vs 20%; $P = .04$). We did not, however, see any significant differences in allergen levels between family and senior citizen buildings (Tables 3 and 4).

For family buildings, we restricted analyses to the 8 buildings with 10 or more participating residents. There were no significant differences in the percentage of apartments with young children, asthmatic patients, or smokers by building. However, there were building-level differences in the number of residents per apartment ($P = .002$) and the percentage of apartments with children ($P = .07$). Pests and their allergen levels varied significantly across buildings (Fig 1). The percentage of apartments with trapped cockroaches ranged from 56% to 95%. Furthermore, the percentage of apartments with high Bla g 2 levels in beds ranged from 0% in one building to 67% in another. There were also significant building-level variations in kitchen allergen levels (data not shown).

Asthma

Asthma prevalence and morbidity were high in this sample. More than one third of the apartments studied (37%) were home to at least 1 resident with asthma. There were 159 residents who had been diagnosed as having asthma by a physician and who were living in the apartments we studied (22% of all residents). Fifty-three asthmatic patients were children younger than 18 years (26% of all children in the apartments studied), and 105 asthmatic patients were adults (20% of all adults). Based on reported symptoms in the 2 weeks before the interview, most asthmatic patients (64%)

Table 4. Comparison of Apartments With Elevated Mouse Allergen (MUP) Levels in Kitchens and Beds With Environmental Conditions*

Home characteristic	Kitchen dust samples (n = 321)			Bed dust samples (n = 269)		
	No.	Apts with high MUP, %†	OR (95% CI)	No.	Apts with high MUP, %‡	OR (95% CI)
Resident sees mice daily						
Yes	56	70	4.8 (2.6–9.0)§	45	42	4.2 (2.1–8.4)§
No	261	32		214	15	
Evidence of mice in the apartment						
Yes	43	49	1.6 (0.9–3.1)	33	39	3.2 (1.5–7.1)¶
No	275	37		227	17	
Site						
East Harlem	165	24	0.3 (0.2–0.4)§	142	18	0.8 (0.4–1.4)
Bushwick	155	54		118	22	
Building type						
Senior citizen	99	43	1.4 (0.8–2.2)	89	21	1.2 (0.6–2.2)
Family	221	36		171	19	
Child aged <7 y lives in the apartment						
Yes	45	38	1.0 (0.5–1.8)	37	38	3.1 (1.4–6.5)¶
No	274	39		223	17	
Open food in the kitchen						
Yes	47	30	0.6 (0.3–1.2)	41	42	3.9 (1.9–7.9)§
No	273	40		219	16	
Clutter in the kitchen						
Yes	105	33	0.7 (0.4–1.2)	88	30	2.5 (1.3–4.6)¶
No	215	41		172	15	

Abbreviations: Apts, apartments; CI, confidence interval; OR, odds ratio.

* Some values do not sum to the appropriate totals because of missing questionnaire data.

† Samples greater than 1 μg/g MUP were categorized as high.

‡ At least 1 bed sampled in the apartment contained high MUP levels.

§ Significant at $P < .001$.

¶ Significant at $P < .01$.

had symptoms consistent with mild intermittent asthma, 12% with mild persistent asthma, and 24% with moderate persistent or severe persistent asthma. Half of the asthmatic patients (49%) reported seeing a physician for asthma in the past 3 months, 27% reported going to the emergency department, and 9% reported being hospitalized. Extrapolating data on reported asthma morbidity in the past 3 months, asthmatic patients averaged 2.1 emergency department visits per year, and working or school-aged asthmatic patients averaged 7.1 days of work or school lost per year due to asthma. Asthma was less common among adults living in the senior citizen buildings (13%) compared with adults living in the family developments (22%) ($P = .03$). Note that we did not record the exact age of all the residents in this study. We do not know whether asthma prevalence among senior citizens living in family buildings was comparable with that of their peers in senior citizen housing.

Relationships Among Pests, Allergens, and Asthma

Univariate analyses indicated relationships among asthma prevalence and allergens and among asthma prevalence and pests. Apartments with 1 or more asthmatic patients were more likely to have beds with high cockroach allergen levels (OR, 2.1; 95% CI, 1.2–3.6) and mouse allergen levels (OR, 2.3; 95% CI, 1.2–4.2). Apartments with 1 or more asthmatic residents also had significantly more cockroaches in the kitchen ($P = .01$) and were more likely to report seeing mice every day ($P = .02$). Of apartments with children, the odds of having an asthmatic child were greater for those with beds containing high cockroach allergen levels (OR, 2.9; 95% CI, 1.1–7.5), but this relationship did not reach statistical significance for mouse allergen levels (OR, 2.1; 95% CI, 0.7–6.5). No significant relationship between kitchen levels of allergens and asthma prevalence was observed. In homes with at least 1 asthmatic resident and a corresponding bed dust sample, we found no significant relationship between allergen concentrations and asthma morbidity (eg, symptoms in the past 2 weeks and emergency department visits, hospitalizations, missed work or school, and physician visits in the past 3 months).

In adjusted analyses of family buildings, apartments with high levels of Bla g 2 in 1 or more beds had 1.7 times greater odds of having asthmatic residents than apartments with low cockroach allergen levels (Table 5). In a separate model that examined the relationship between mouse allergen levels in beds and asthma prevalence controlling for the same potential confounders, there was no significant relationship between high mouse allergen levels and asthma prevalence. The inclusion of an interaction term between children and allergens

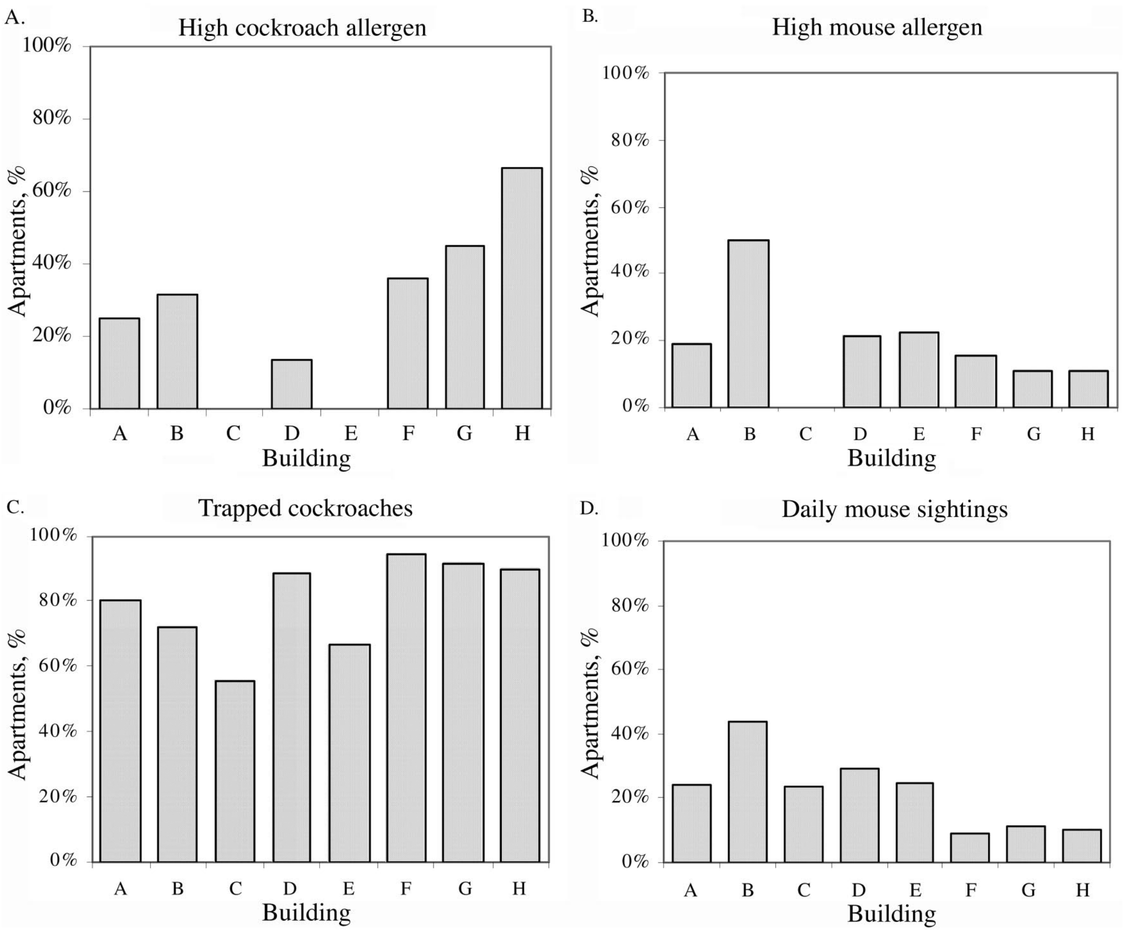

Figure 1. Variability in the percentage of apartments with high bed Bla g 2 allergen levels (>8 U/g) (A), high bed mouse urinary protein (MUP) allergen levels (>1 μg/g) (B), trapped cockroaches (C), and daily mouse sightings (D) in the 8 buildings located in family housing in which residents in at least 10 apartments participated in the study. There was significant building-level variability in the percentage of apartments with high Bla g 2 levels (P = .002), high MUP levels (P = .03), trapped cockroaches (P = .002), and daily mouse sightings (P = .02).

did not significantly improve the model. In adjusted analyses of senior citizen buildings, we found no significant relationship between diagnosis of asthma and bed Bla g 2 levels. However, apartments with high bed mouse allergen levels were significantly more likely to have an asthmatic resident, controlling for smoking, building, and having more than 1 resident in the apartment (adjusted OR, 6.6; 95% CI, 1.4–31.7).

DISCUSSION

We found that cockroaches, mice, and their respective allergens varied greatly between buildings, between apartments, and within apartments in this sample of New York City public housing developments. Some of this variability could be due to differences in home characteristics that vary by building in this study (eg, the percentage of apartments with children and differential use of pesticides). The high prevalence of asthma in the present study implies that effective allergen intervention should include building-wide strategies.

Cockroaches, Mice, and Their Allergens

Cockroach infestation was more common than mouse infestation in the study homes, and cockroach allergen levels were associated with report and measurement of cockroaches. The percentage of residents reporting cockroaches in their homes in this study (93%) was similar to that in another New York City cohort (88%).[24] Also, the percentages of kitchens and beds with high cockroach allergen levels were similar to those observed in the Bronx and New York City study sites in the ICAS population (62% in beds or floors).[4] In the present study, participants reported mice in their homes with the same prevalence as that observed in the multisite NCICAS population (49%)[16] but with a lower prevalence than that of another study conducted in New York City (71%).[24]

Table 5. Relationship Between Bed Allergen Levels and the Number of Asthmatic Individuals in Apartments, Controlling for Potential Confounders

Variable	Ratio (95% CI) of predictor to reference category*	
	Family buildings	Senior citizen buildings
Bla g 2 and asthma		
Bla g 2 >8 U/g in ≥1 beds	1.7 (1.2–2.3)†	1.2 (0.2–6.5)
Children live in the apartment	1.8 (1.2–2.5)†	Not included in model
>1 resident lives in the apartment	Not included in model	1.3 (0.1–12.8)
Smoker present in the apartment	1.2 (0.9–1.7)	0.3 (0.0–2.8)
Building	‡	0.3 (0.1–1.1)§
MUP and asthma		
MUP >1 μg/g in ≥1 beds	1.2 (0.8–1.8)	6.6 (1.4–31.7)‖
Children live in the apartment	1.9 (1.3–2.8)¶	Not included in model
>1 resident lives in the apartment	Not included in model	1.3 (0.1–14.6)
Smoker present in the apartment	1.1 (0.8–1.6)	0.2 (0.0–2.6)
Building	‡	0.2 (0.0–0.8)§‖

Abbreviations: CI, confidence interval; MUP, mouse urinary protein.
* In the family building analysis, we used a Poisson regression model to account for the variable number of residents and asthmatic individuals in each apartment. Therefore, risk ratios are reported for family buildings, whereas odds ratios are reported for senior citizen buildings. Because most residents in the latter buildings lived alone, a logistic regression model was used.
† $P < .01$.
‡ In the multilevel model for family buildings, the building variable was not significant for Bla g 2 and asthma or MUP and asthma ($P = .80$ and $P = .84$, respectively).
§ The senior citizen building in Bushwick was the reference building.
‖ $P < .05$.
¶ $P < .001$.

Furthermore, the median mouse allergen levels in NYCHA kitchens and bedrooms were moderately lower than those observed in the NCICAS (1.6 and 0.5 μg/g, respectively) and the other New York City study (2.0 and 0.5 μg/g, respectively). The mouse allergen levels bore more of a resemblance to those from primarily single-family houses in the National Survey of Lead and Allergens in Housing (0.36 and 0.25 μg/g).[27] However, several caveats must be considered when comparing the present results with those of the NCICAS or other studies: (1) building type and neighborhood differences exist between studies, (2) different cockroach and mouse allergen assays were used (although the correlations between Bla g 1 and Bla g 2 and between MUP and Mus m 1 are statistically significant[28,29]), and (3) different time frames were considered when asking residents about reports of mice or cockroaches. It is also true that nonparticipation could limit the generalizability of these study results. We did not have information regarding infestation levels in apartments in which residents did not consent to participate. Therefore, it remains unknown whether this sample overestimated or underestimated the levels of pest infestation, allergens, and pesticide use in the buildings studied. Some residents might have refused to participate for a variety of reasons; however, these limitations are likely to occur in other studies of pests and asthma in public and private housing.

We also found that allergen measurements were strongly correlated between beds and kitchens but that the levels were much higher in kitchens. Furthermore, we found that allergen in beds is more strongly associated with asthma prevalence than the higher levels of allergen in kitchens. Exposure to bed dust near the breathing zone for approximately 8 hours each night could represent a more relevant allergen exposure than that of kitchen dust. Are the allergens coming from microenvironments within the rooms or are they being tracked from the kitchen into the bedroom? The finding that kitchens tended to have more cockroaches than bedrooms along with the previous speculation that this correlation was due to the small distance between kitchens and beds in inner-city New York City apartments[24] suggests that cockroach allergen can be tracked from kitchens to bedrooms. The same argument cannot necessarily be made for mouse allergen, and future research should explore the mechanisms of exposure to these allergens to design truly effective intervention strategies.

Associations Between Home Characteristics and Allergens

We found that the presence of young children, open food, and clutter in the kitchen was associated with high bed allergen levels (MUP >1 μg/g and Bla g 2 >8 U/g). However, these variables were not associated with MUP levels greater than the median (0.28 μg/g), and neither were they associated with high kitchen allergen levels. The stronger associations with bed dust could be because bed dust is more homogeneous than kitchen dust, which is strongly affected by dramatic changes in composition and weight (eg, spilling flour or salt on the kitchen floor). The associations among the presence of children, clutter, open food, and high allergen levels are complex. Although the associations are logical and have been found or suggested elsewhere,[1,27] it remains to be determined whether these are in fact distinctly apartment-level characteristics that are not intertwined with building or neighborhood characteristics. For example, homes in the suburbs with children or open food sources will not necessarily have high mouse or cockroach allergen levels. Clearly, the choice of different threshold values has the potential to affect which home characteristics are associated with high allergen levels.[16,27,30,31] Regardless of the threshold of high allergen exposure, the resident-reported presence of mice or cockroaches was consistently associated with high levels of their respective allergens, consistent with previous studies.[16,17,27,30,31]

One of the most novel findings of this baseline analysis is that allergen levels varied greatly by building. Although previous studies have investigated between-apartment differences, none thus far have investigated between-building differences within public housing complexes. Similar to other studies,[16,31] we found that cockroach allergens were moderately correlated with mouse allergens overall; however, the percentage of apartments with high cockroach allergen levels was sometimes very different from the percentage with high mouse allergen levels in the same building. Also notable in this study are the striking differences between apartments in the senior citizen vs family buildings. Although the residents in senior citizen buildings were seemingly less exposed to mice and cockroaches compared with residents in the family buildings, their allergen levels did not reflect this difference. The reason for this discordance between pests and their allergen levels is unclear, but it could be due in part to the limited number of senior citizen buildings ($n = 2$) and the wide variation in levels of allergens in the family buildings. Nonetheless, the fact that some buildings did not have any apartments with high allergen levels and some buildings had high levels in most apartments highlights the need to consider building-wide factors when assessing exposure and designing interventions.

Pesticides

Most residents in the buildings we studied reported using lower-toxicity pesticides, particularly insecticide baits. This news is encouraging and suggests a willingness to try less harmful pest control products. Previous research in low-income minority neighborhoods in New York City demonstrated a similar trend toward nonspray pesticides. One survey found that more than 95% of women were concerned about the health risks of residential pesticides.[32] Another found that most storekeepers recommended lower-toxicity products to control cockroaches.[33] Still, some respondents in the present study might not have admitted using illegal pesticides. Measurement of pesticide residues could help validate the self-reported use, but such measurements might not accurately reflect pesticide use by the current occupant.

In light of these findings, the association between higher-toxicity pesticide use and the severity of cockroach infestation suggests that higher-toxicity pesticides might serve as a last line of defense against cockroaches. Furthermore, the use of illegal pesticides may reflect a lack of awareness about labeling requirements and a willingness to use anything to eliminate cockroaches. The percentage of residents reporting cockroaches in the buildings we studied is higher than that documented in past studies in New York City, as is the percentage of residents who report using pesticides to control cockroaches.[34,35] Campaigns aiming to reduce the use of spray and illegal pesticides must focus on more than educating residents about the hazards of such pesticides. They must offer effective alternatives that will reduce cockroach populations.

Asthma

In this study, we found high asthma prevalence in a wide age range of residents living in the same public housing complexes. This is not unexpected given that the study location is the inner city, which is known to have a disproportionate burden of asthma.[1,4,36] The prevalence of asthma was strongly associated with high cockroach and mouse allergen concentrations in the home, particularly in the beds. Residents of the senior citizen building were greater than 6 times more likely to have an asthma diagnosis if their beds had high mouse allergen levels compared with those with low levels, adjusting for confounders. For the family buildings, the association between cockroach allergen levels and the presence of an asthmatic resident in the apartment was smaller but consistent with findings from other studies.[36,37] Furthermore, we did not see any associations with cockroach and mouse allergen levels and asthma morbidity, associations that have been found in other studies.[1,4,36] Because we did not collect information on allergen sensitivity, it is difficult to know whether the cockroach or mouse allergens were in fact causing the high asthma prevalence or whether they serve as a surrogate for some other factor associated with asthma. The lack of an association between allergen levels and asthma morbidity is puzzling but could be partly due to high intra-apartment variability in allergen levels. We also cannot rule out the possibility that residents with severe asthma (or the caregivers of such residents) may have received advice from health care providers, media outlets, and the New York City DOHMH to reduce cockroach populations based on the link between cockroach allergen and asthma. Although it is difficult to show causality with this cross-sectional design and lack of allergen sensitivity information, the implications for public health are significant, and allergen exposure especially among elderly people should be investigated further considering that they are also at risk for fatal asthma attacks.

In conclusion, high pest allergen levels are shaped by apartment-level conditions and building factors. This finding suggests that it matters not only how the individual resident controls pests but also how neighboring residents, building managers, and landlords mitigate conditions that support infestations. High cockroach and mouse allergen levels were also significantly associated with asthma prevalence in children and adults, controlling for potential confounders. These findings, along with the use of higher-toxicity pesticides by residents with more cockroaches, underscore the need for safe and effective building-wide pest control strategies.

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